Overview on systems for process heat applications

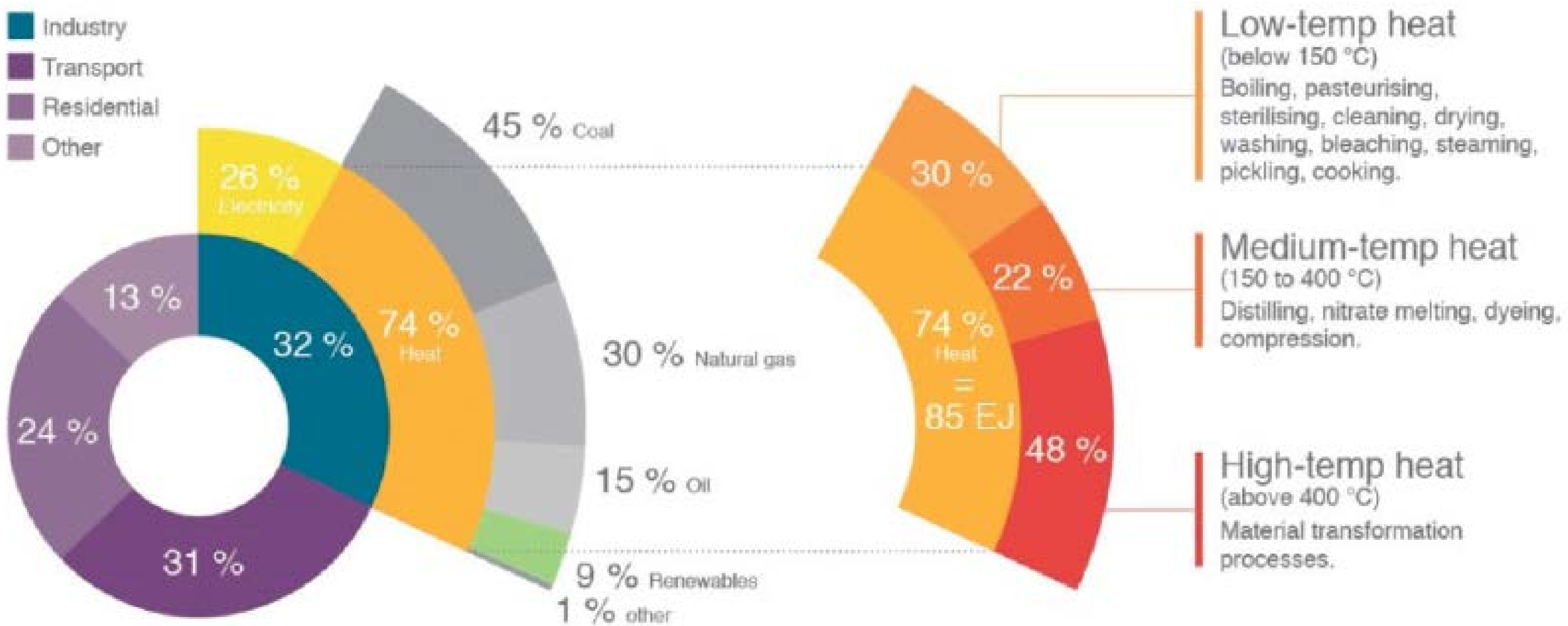
German Aerospace Center (DLR)

Institute of Solar Research

Dr. Peter Heller, Klaus Hennecke

DLR

Significance of industrial process heat demand



Note: EJ = exajoule.

Source: Solar Payback (2017), based on IEA statistics and calculations by IRENA.

Key message • **Heat represents three-quarters of industrial energy demand worldwide, and half of it is of low to medium-high temperature.**

Source: C. Philibert, IEA Insight Series 2017 „Renewable Energy for Industry“

Renewable Energy Technologies for Power Generation

Hydro

Solarthermal

Biomass

Geothermal

Tidal

Wave

Photovoltaic

Wind

Renewable Energy Technologies for Process Heat

Geothermal

Concentrating Solar

Biomass

Non-concentrating Solar

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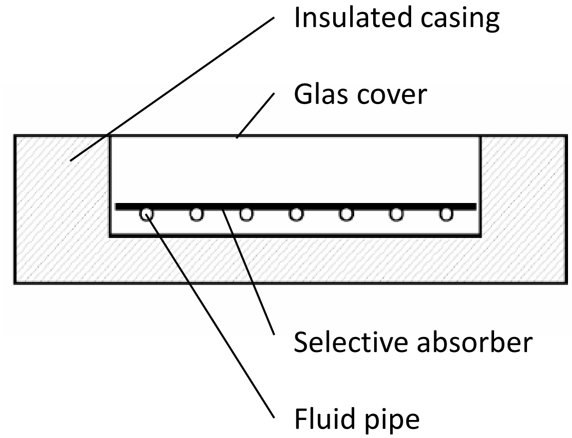
Collector technologies on the market (1/2)

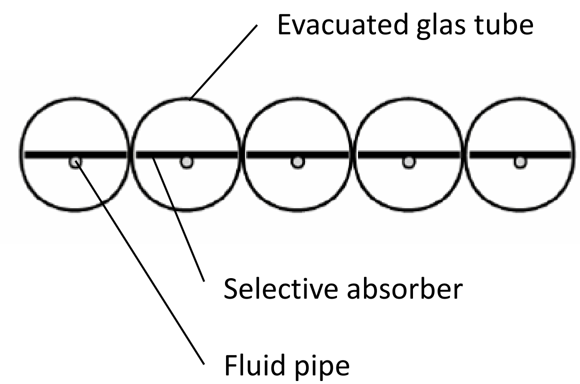
Flat plate

C: =1
T: < 100°C
P: ~ 1 kW – 10 MW
Domestic hot water, space heating, process heat



Evacuated tube

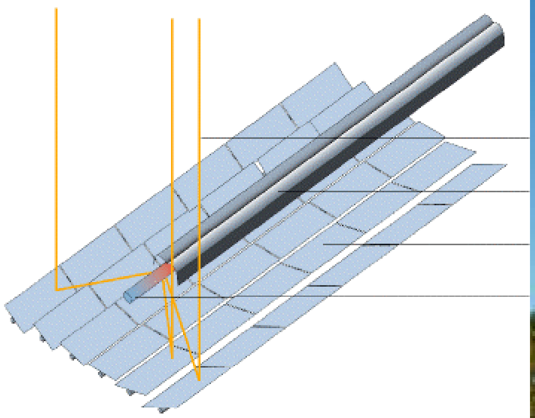
C: < 4
T: < 150°C
P: ~ 1 – 100 kW
Domestic hot water, space heating, process heat



Collector technologies on the market (2/2)

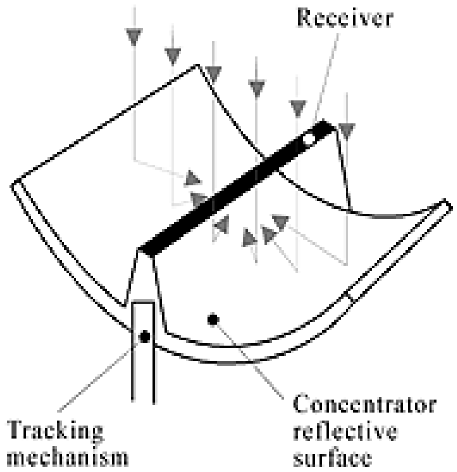
Linear fresnel

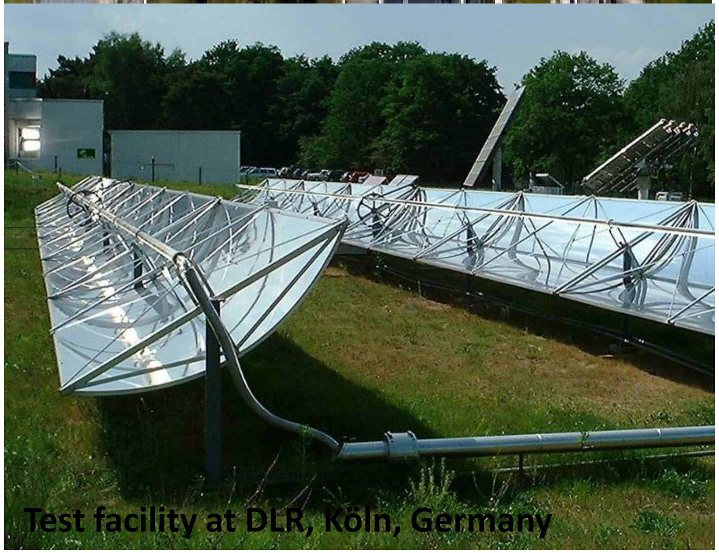
C: < 100
T: < 500°C
P: ~ 0,1 – 1000 MW
Process heat,
Electricity generation
Polygeneration



Parabolic trough

C: < 100
T: < 500°C
P: ~ 0,1 – 1000 MW
Process heat,
Electricity generation
Polygeneration



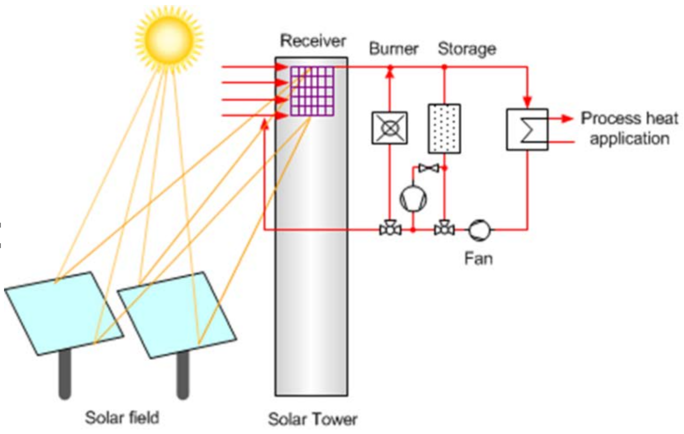


Emerging options for high temperature applications

Solar tower

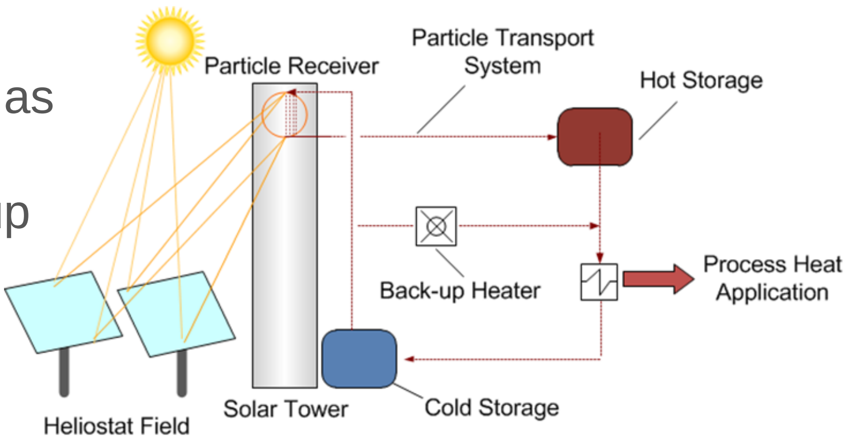
Open volumetric receiver

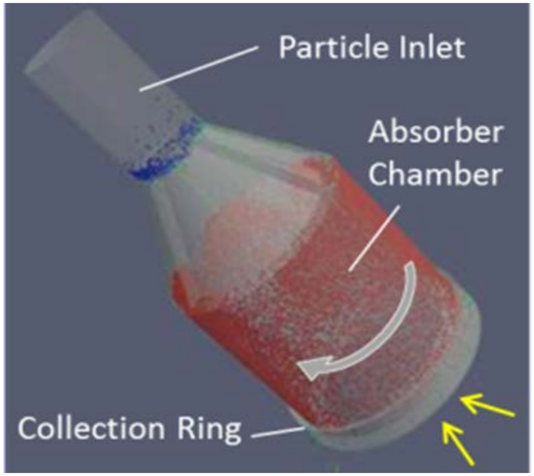
- Proven technology: hot air up to 680°C (solar tower plant Jülich, 10MW$_{th}$)



Particle receiver

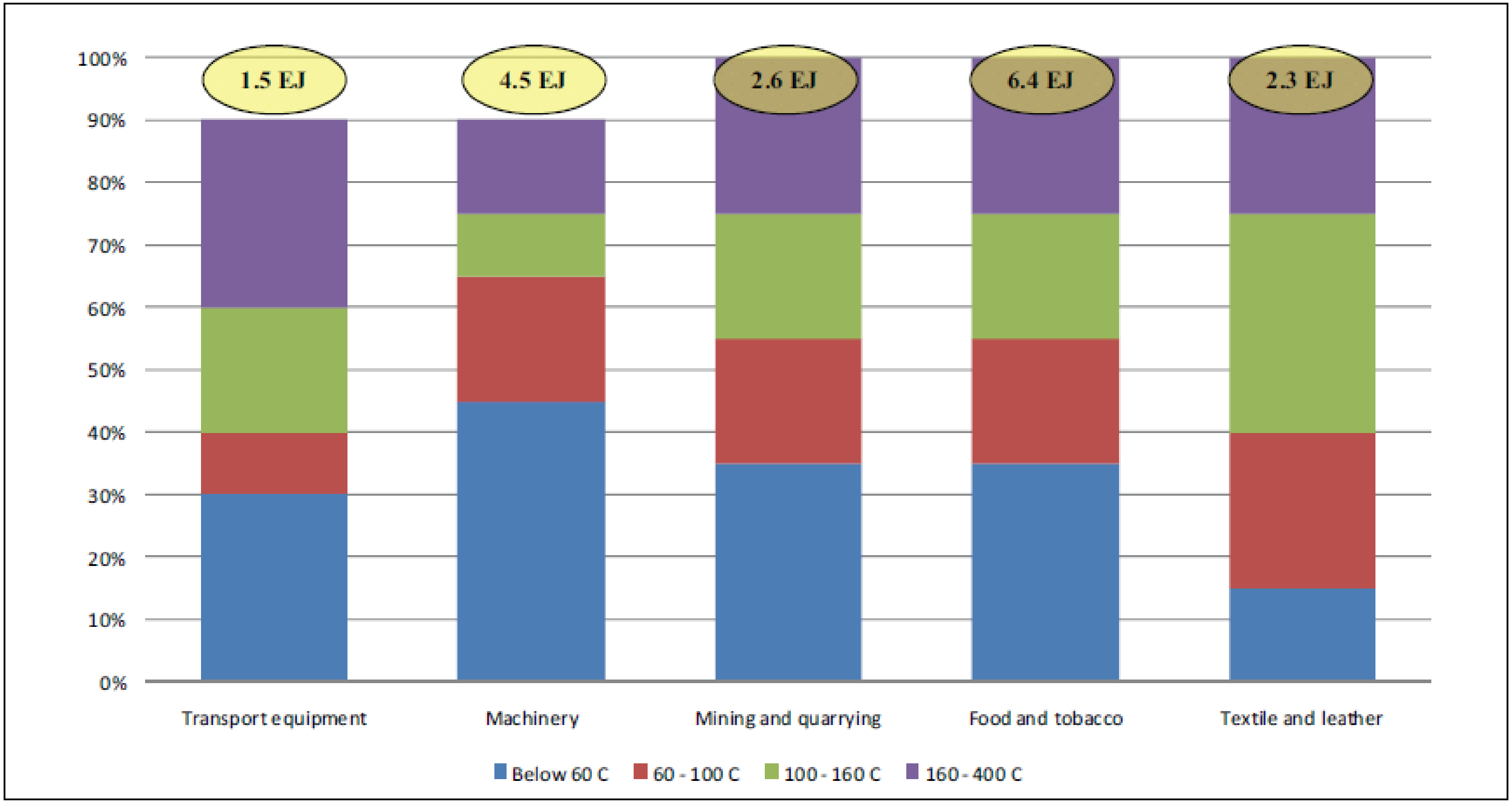
- Ceramic particles as heat transfer and storage medium up to 1000°C
- 2,5 MW$_{th}$ receiver under test





Near term markets

Low and medium temperature process heat demand by sector (Taibi 2010)

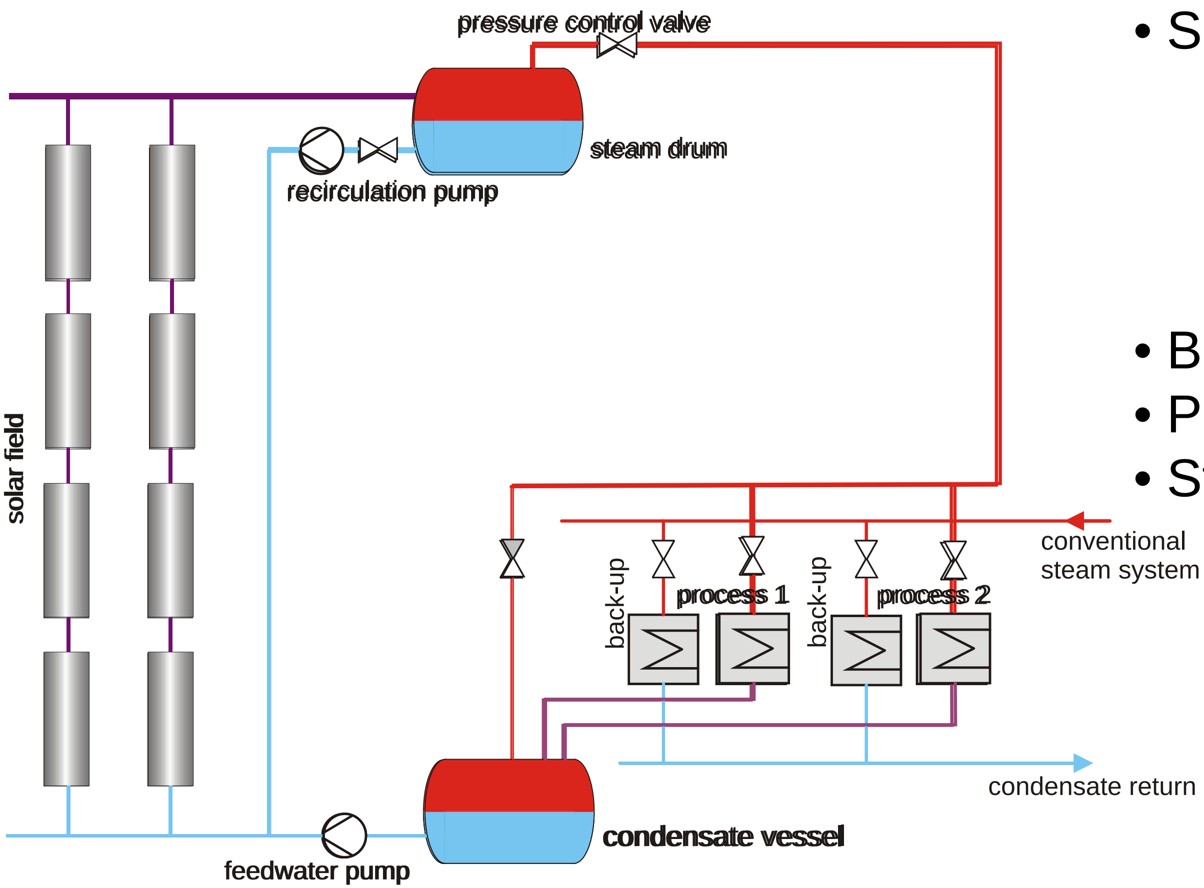


Source: UNIDO (2010) „Renewable Energy in Industrial Applications – an assessment of the 2050 potential“

Challenges in Solar Process Heat

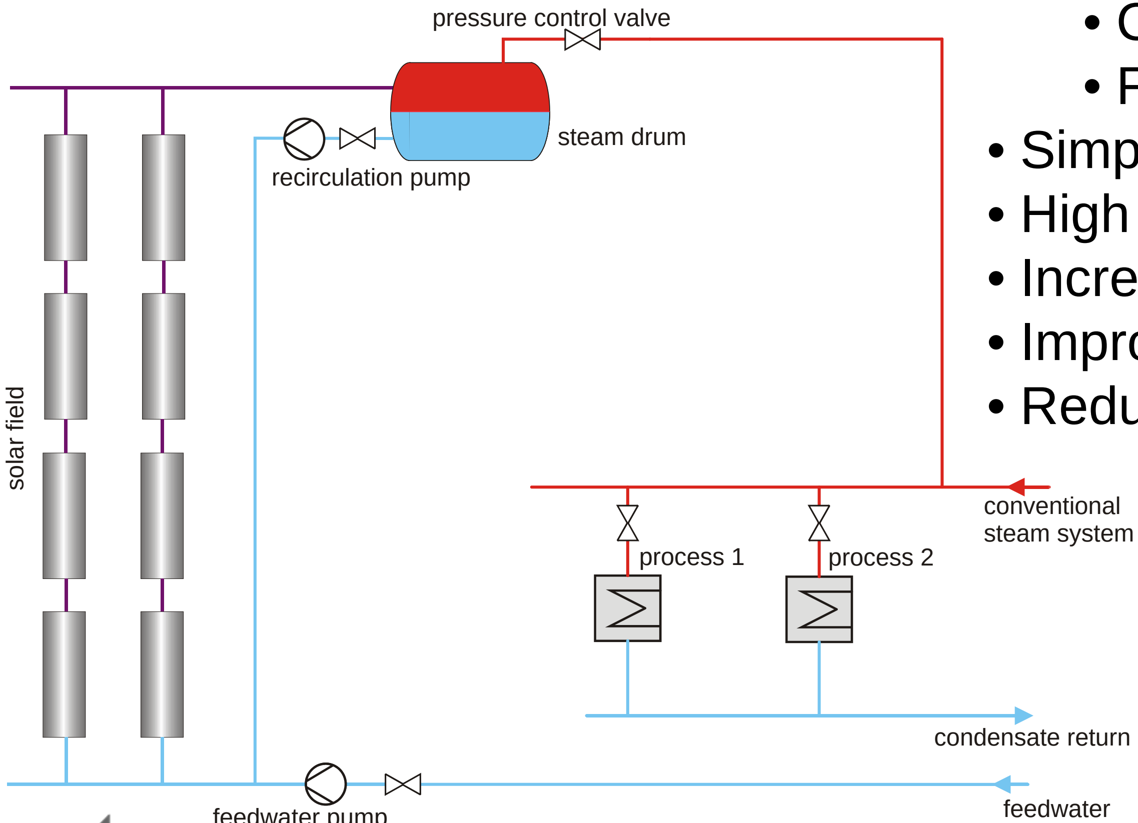
- Heat cannot be transported easily over long distances
  - Meteorological conditions at the site
  - Availability of suitable areas for collectors (ground, roof, facades)
- Solar field size (= investment cost) proportional to thermal power
  - Rational use of energy minimizes heat demand
  - Process optimization often more cost effective than solar energy
- Collector efficiency temperature dependent
  - Selection of suitable collector technology
  - Integration of solar heat at appropriate temperature
- Annual, daily and stochastic variations of radiation
  - Load management, heat storage or conventional back-up
  - Similar load and radiation profiles may increase solar share
- O&M effort for additional technology
  - Priority for O&M personnel: Efficient production
  - Fully automated solar operation

Direct steam supply to selected processes



- Optimized temperature level
- Separate solar heat system
  - Steam distribution
  - Condensate return
  - Feedwater treatment
  - Safety features
- Back-up Control
- Process demand profiles
- Storage requirements

Indirect steam supply via existing steam distribution



- Utilisation of existing infrastructure
  - Steam Distribution
  - Condensate return
  - Feedwater treatment
- Simple back-up control
- High security of supply
- Increase of potential solar share
- Improved solar capacity factor
- Reduced storage requirement

Solar Process Heat
RAM-Pharma, Amman, Jordan

INDUSTRIAL SOLAR
thermal solutions

- Direct steam generation in Fresnel collector field (394 m²)
- Start of operation: March 2015
- 160 °C

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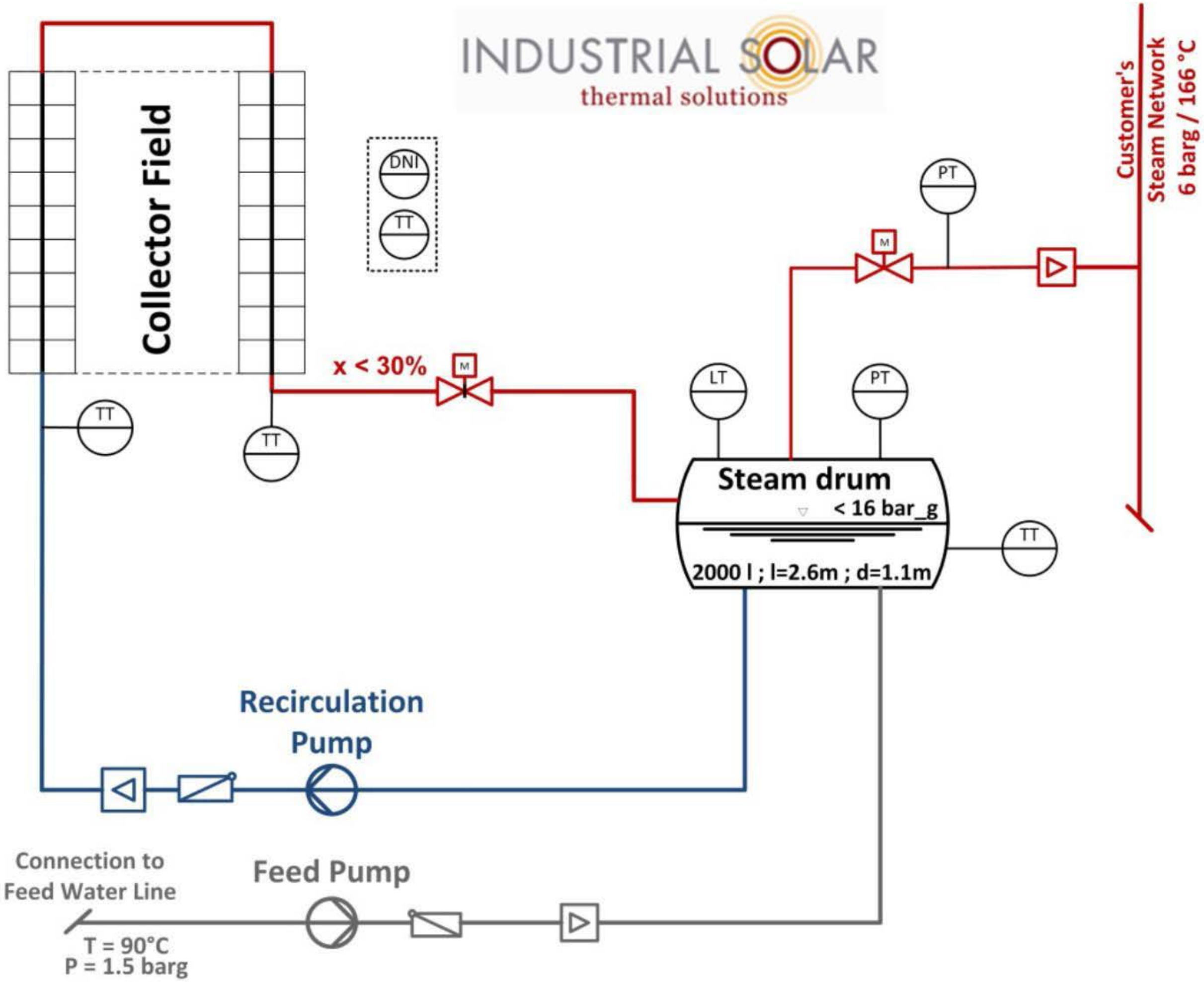
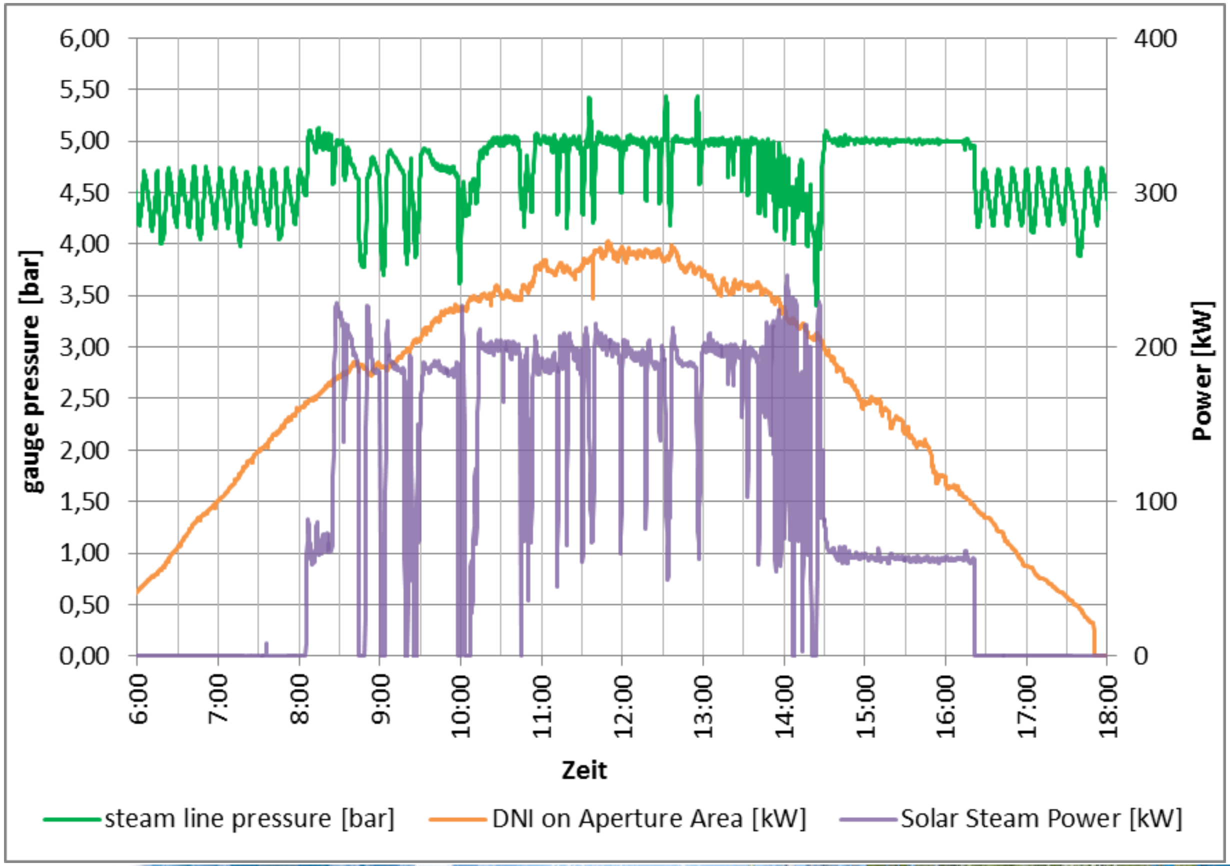
Solar Process Heat
RAM-Pharma, Amman, Jordan

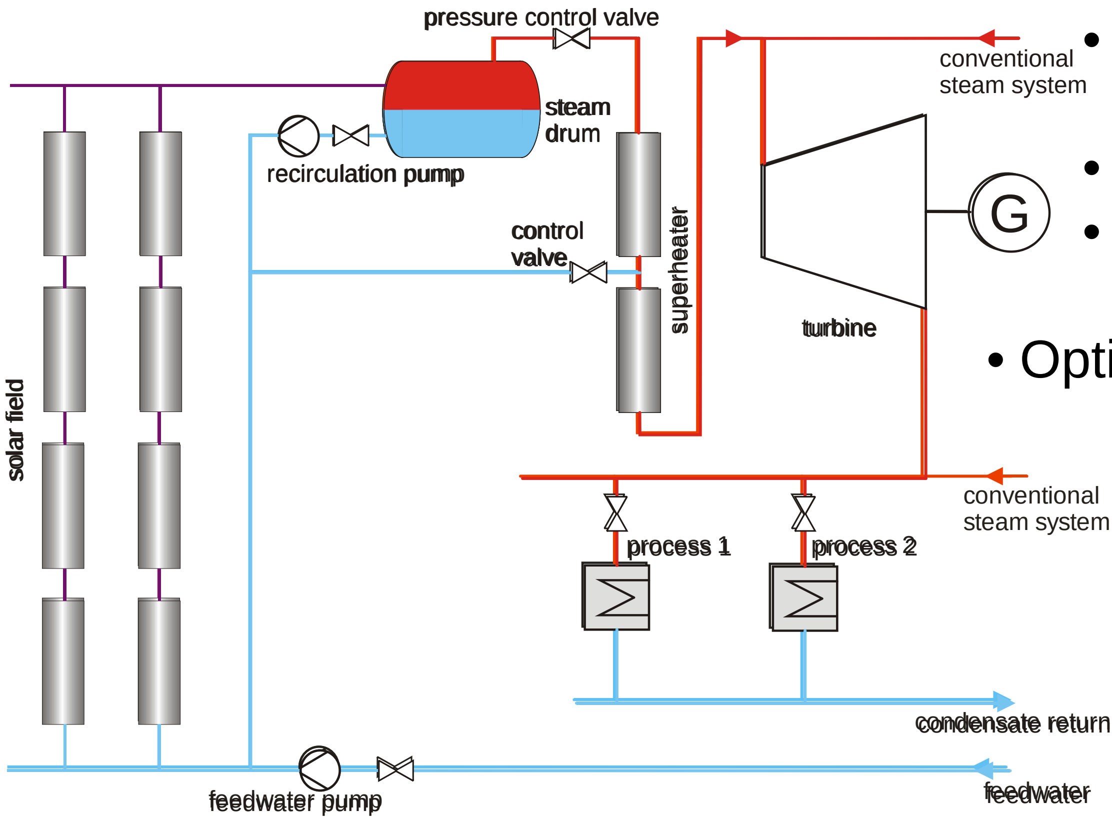


Solar Process Heat
RAM-Pharma, Amman, Jordan

- 30.06.2016: High irradiation & High demand
- Symbiosis of fossil boiler and solar field works well



High pressure steam for co-generation



- Exploitation of exergy potential of concentrating collectors
  - Added value from electricity production
  - Increased investment
  - Increased complexity
- Option: hybrid co-generation

Solar-aided cogeneration
for Brazilian sugar cane industry

UFSC
INSTITUTO FEDERAL SANTA CATARINA
UNIFESP
UNIVERSITÄT DUISBURG ESSEN

Background:

- Sugar and alcohol production from sugar cane is an important industry sector in Brazil
- Residual bagasse is used in biomass combined heat and power plants
- About 360 plants providing 6% of installed capacity
- Typical parameters:
  - 30 MW (20 MW own consumption, 10 MW into grid)
  - Live steam 67 bar / ~ 500 °C
- Operation during harvest season April – December

Aim:

- Extend operating time into off-season
- Improve capacity factor

Funded in the framework of
Brazilian-German i-NoPa Cooperation Program Concentrated Solar Power (CSP) by:

cooperação alemã giz DAAD CAPES Ministério da Educação Ministério da Ciência, Tecnologia e Inovação Ministério das Cidades GOVERNO FEDERAL BRASIL PAÍS RICO É PAÍS SEM POBREZA

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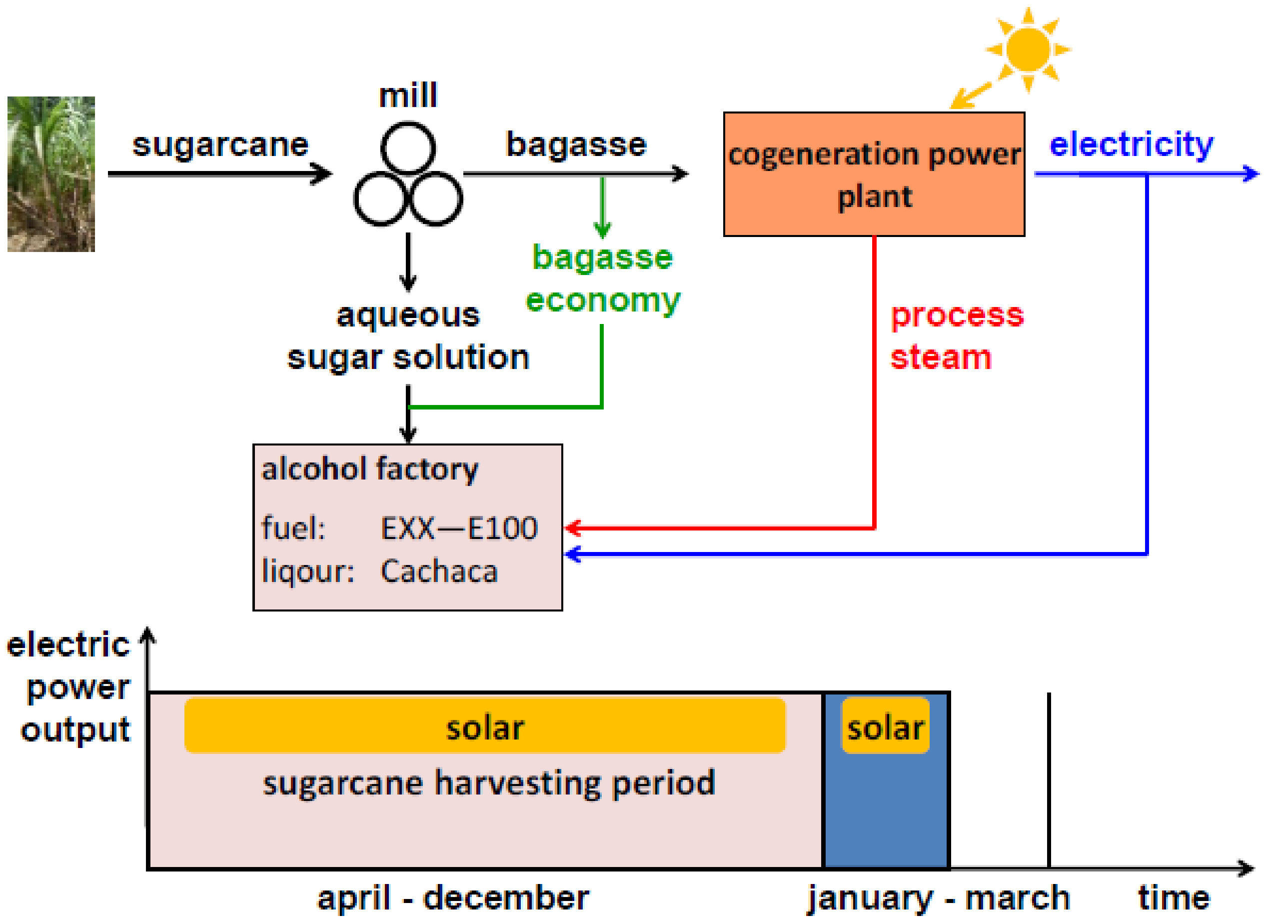
Solar-aided cogeneration
for Brazilian sugar cane industry

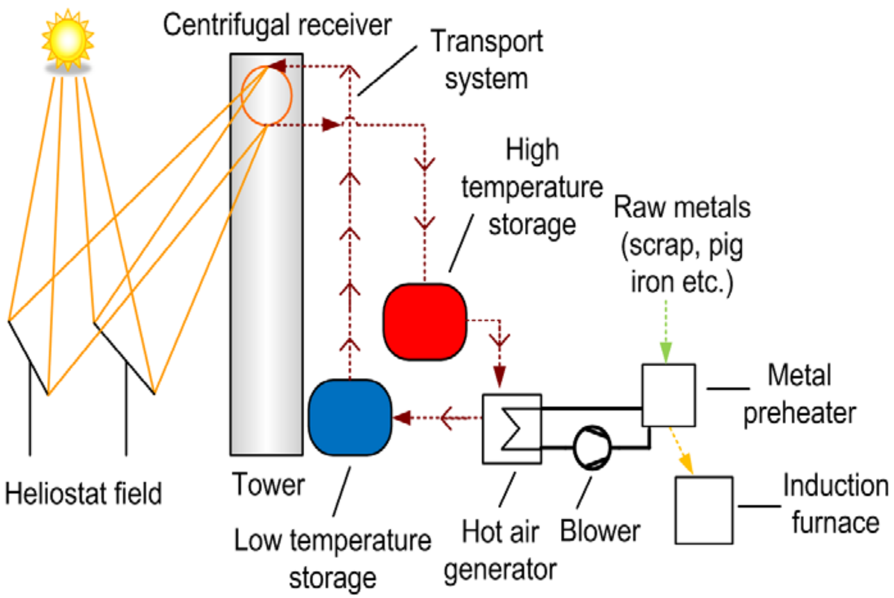
Concept idea



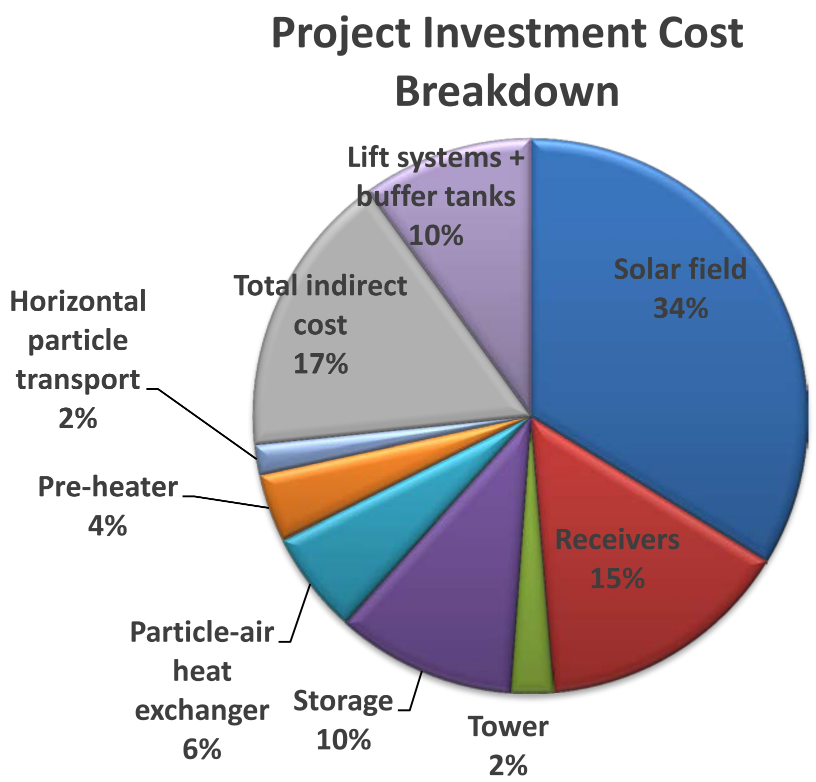
Source: UFSC

Pre-heating in foundries with induction furnaces to save electricity

Case study for foundry in Brazil, State of Sao Paulo



- Particle receiver technology
- Investment costs: 9.7 M€
- Payback time: 4 years
  (without subsidies and bank loans)



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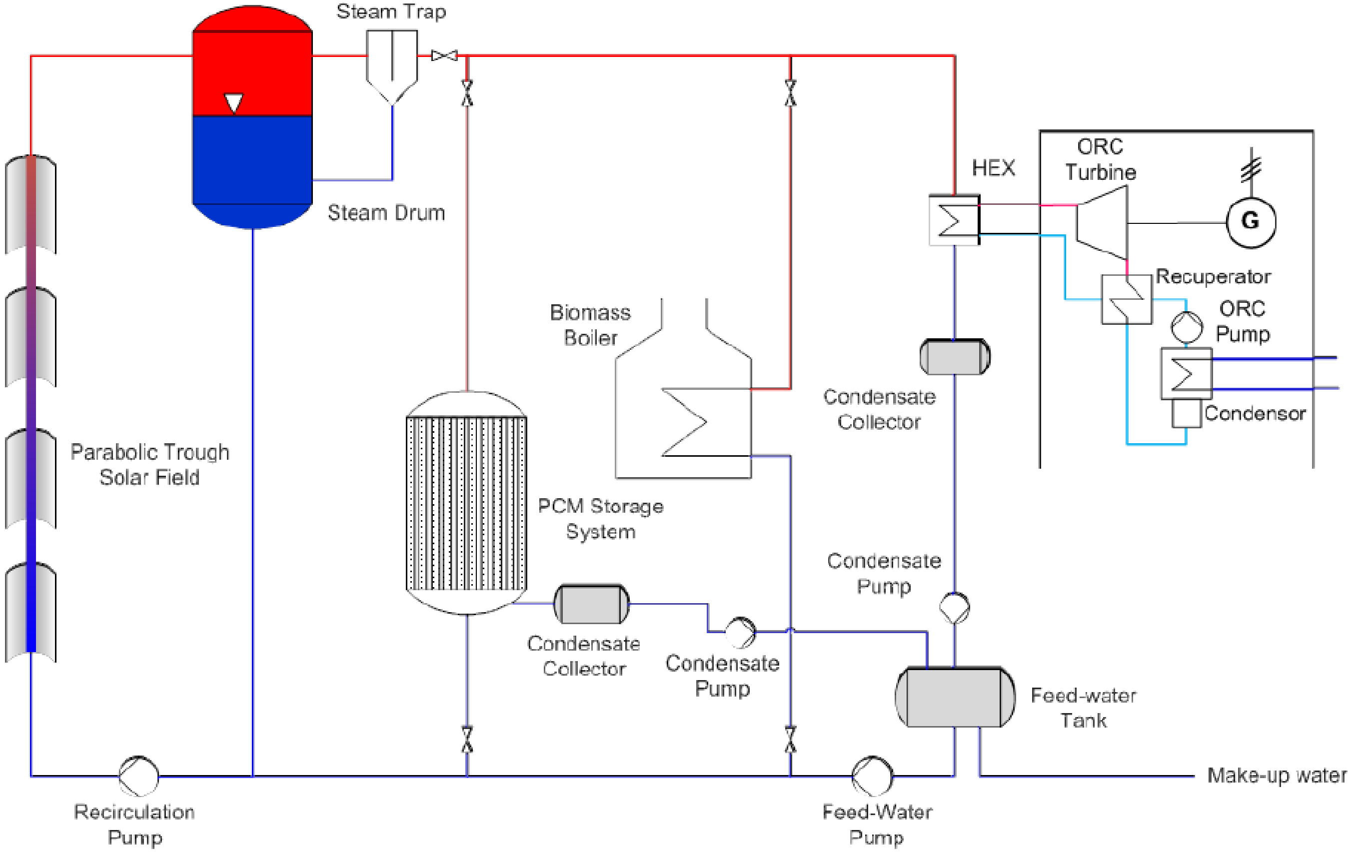
Small scale solar power ReelCoop (EU-funded) Enit, Tunis, Tunisia

- Site status May 2016

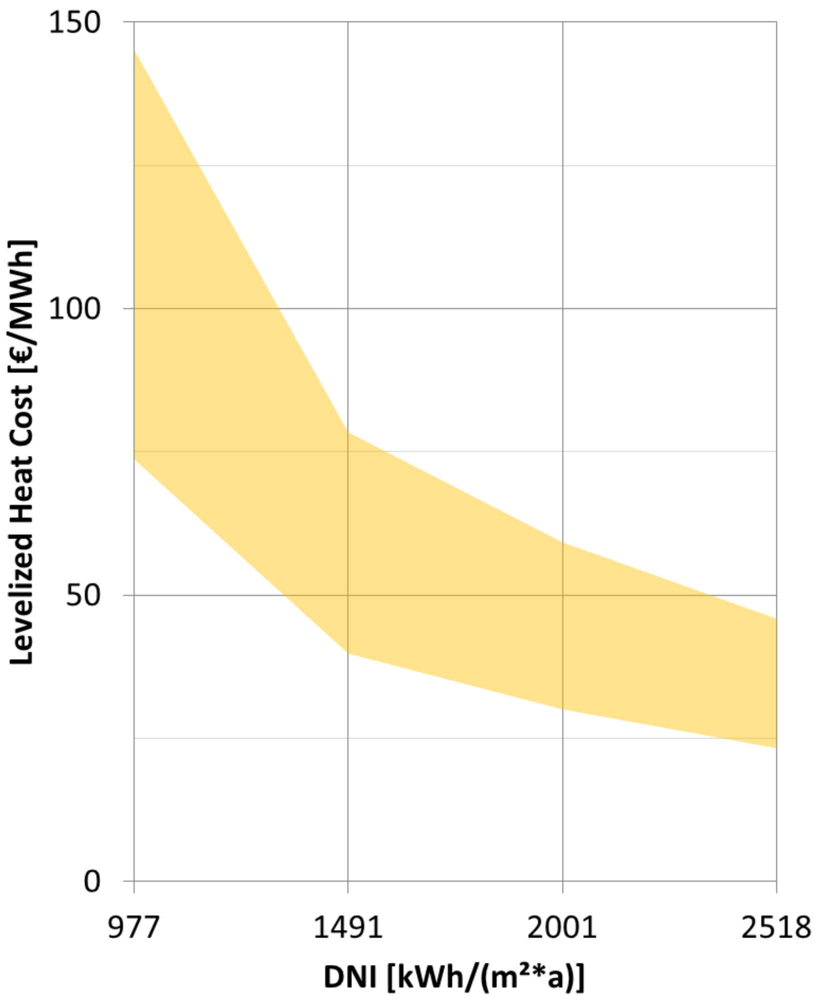
Small scale solar power ReelCoop (EU-funded) Enit, Tunis, Tunisia

- Direct steam generation 1000 m²
- ~500 kW_{th} / 60 kW_{el} Organic Rankine Cycle
- 170 °C / 8 bar



Cost estimate for solar process heat

- Assumptions:
  - Parabolic trough with evacuated absorber tube
  - Outlet temperature 140°C
  - Nominal thermal power: 10 MW_{th}
- Lower boundary:
  - Specific solar field cost 240 €/m²
  - All solar heat can be used (process demand always higher than solar field output)
  - Heat cost at solar field outlet (no integration cost)
- Higher cost possible due to
  - Smaller solar field (higher specific cost)
  - Energy dumping due to lack of demand
  - Integration cost, balance of plant



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Potential Support

- Feasibility studies
  - Concept development and evaluation
  - Technology recommendation

- Technology development / adaption
  - Increase local content (materials, labour)

- Planning, construction supervision, start-up of solar facilities
  - Consulting support for client
  - Liaison with technology suppliers

- Training

- Monitoring of operation
  - Feedback of practical experience
  - Future improvements

Thank you for your attention

peter.heller@dlr.de

klaus.hennecke@dlr.de